10-24-00

23351
PATENT_TRADEMARK OFFICE

A

Practitioner's Docket No. 16220-1

PATENT

JC575 U.S. PTO
10/23/00

Preliminary Classification:
Proposed Class:
Subclass:

jc913 U.S. PTO
09/696527
10/23/00

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Box Patent Application
Assistant Commissioner for Patents
Washington, D.C. 20231

NEW APPLICATION TRANSMITTAL

Transmitted herewith for filing is the patent application of

Inventor(s): Ji (nmi) SU; Joycelyn S. HARRISON

For (title): MEMBRANE TENSION CONTROL

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CERTIFICATION UNDER 37 C.F.R. SECTIONS 1.8(a) AND 1.10*
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37 C.F.R. Section 1.10*

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TRANSMISSION

[ ] transmitted by facsimile to the Patent and Trademark Office (703) ____-____.

Date: Oct. 23, 2000

Robin W. Edwards
Signature

ROBIN W. EDWARDS
(*type or print name of person certifying*)

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1. **Type of Application**

This transmittal is for an original (nonprovisional) application.

2. **Papers Enclosed**

A. Required for filing date under 37 C.F.R. 1.53(b) (Regular) or 37 C.F.R. 1.153 (Design) Application

5 Page(s) of Specification
5 Page(s) of Claims
3 Sheet(s) of Drawing(s)--Informal

B. Other Papers Enclosed

2 Page(s) of declaration and power of attorney–inventors unavailable for signature
1 Page(s) of Return Postal Card

3. **Declaration or Oath**

Enclosed
Unexecuted by:
* inventors.

4. **Inventorship Statement**

The inventorship for all the claims in this application is the same.

5. **Language**

English

6. **Assignment**

An assignment of the invention to Administrator, National Aeronautics and Space will follow.

7. **Fee Calculation (37 C.F.R. Section 1.16)**

Regular Application

CLAIMS AS FILED

Claims	Number Filed	Basic Fee Allowance	Number Extra		Rate	Basic Fee 37 CFR 1.16(a) $710.00
Total Claims (37 CFR 1.16(c))	30	- 20 =	10	x	$18.00	$180.00
Independent Claims (37 CFR 1.16(b))	2	- 3 =	0	x	$80.00	$0.00
Multiple Dependent Claim(s), if any (37 CFR 1.16(d))				+	$270.00	$0.00
			Filing Fee Calculation			$890.00

8. **Fee Payment Being Made at This Time**

Enclosed

Filing Fee	$890.00
Total Fees Enclosed	$890.00

9. **Method of Payment of Fees**

Charge Account No. 14-0116 in the amount of $890.00.
A duplicate of this transmittal is attached.

10. **Authorization to Charge Additional Fees**

The Commissioner is hereby authorized to charge the following additional fees by this paper and during the entire pendency of this application to Account No. 14-0116.

37 C.F.R. Section 1.16(a), (f) or (g) (filing fees)
37 C.F.R. Section 1.16(b), (c) or (d) (presentation of extra claims)
37 C.F.R. Section 1.16(e) (surcharge for filing the basic filing fee and/or declaration on a date later than the filing date of the application)
37 C.F.R. Section 1.17(a)(1)-(5) (extension fees pursuant to SECTION 1.136(a))
37 C.F.R. Section 1.17 (application processing fees)
37 C.F.R. Section 1.18 (issue fee at or before mailing of Notice of Allowance, pursuant to 37 C.F.R. Section 1.311(b))

11. Instructions as to Overpayment

Credit Account No. 14-0116.

12. Relate Back

Amend the specification by inserting, before the first line, the following sentence:
N/A

13. Maintenance of Copendency of Prior Application

A. Conditional Petition for Extension of Time in Prior Application
A conditional petition for extension of time is being filed in the pending **prior** application.
N/A

14. Further Inventorship Statement Where Benefit of Prior Application(s) Claimed

Date: Oct. 23, 2000

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Practitioner's Docket No. LAR 16220-1 *PATENT*

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: SU, Ji (nmi); HARRISON, Joycelyn S.

Application No.: Group No.:
Filed: Examiner:
For: MEMBRANE TENSION CONTROL

Assistant Commissioner for Patents
Washington, D.C. 20231

EXPRESS MAIL CERTIFICATE

"Express Mail" label number EK161582130
Date of Deposit 10/23/2000

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NEW UTILITY PATENT APPLICATION

is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 C.F.R. section 1.10, on the date indicated above and is addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231.

ROBIN W. EDWARDS

Robin W. Edwards

Signature of person mailing paper or fee

Return Postal Card
Org & 1 transmittal form
Specification, Claims, Abstract - 11 pgs
Declaration (NASA Form 1538)
3 sheets INFORMAL drawings

MEMBRANE TENSION CONTROL

Claim of Benefit of Provisional Application

Pursuant to 35 U.S.C. §119, the benefit of priority from provisional application 60/161,113, with a filing date of October 22, 1999, is claimed for this non-provisional application.

Cross Reference to Related Cases

This application is related to co-pending, commonly owned patent application Serial No. _____, filed October 23, 2000, entitled "Electrostrictive Graft Elastomers."

Origin of the Invention

The invention described herein was made by an employee of the United States Government and a National Research Council Research Associate and may be used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

Background of the Invention

Field of the Invention

The present invention is generally related to tension control of membranes using an electroactive actuator having at least predominantly single axis displacement.

Description of the Related Art

Membrane inflatable and deployable space structures are widely employed by the government and commercially as reflectors, antennas, solar arrays, satellites, solar sails, etc. Although these membrane inflatable and deployabe structures are widely used, many challenges exist which limit their performance for high precision applications. Factors affecting precision include surface smoothness, deviation from desired surface profile, surface deformations due to thermal fluctuations, and accurate membrane positioning. Actuation devices are used for many applications, including the shaping, tuning, positioning, controlling and deforming of membrane structures. To operate most effectively in the aforementioned applications, actuation devices require sufficient force and strain, and often need to produce complex motions.

Conventional piezoelectric ceramic, polymer, and composite actuators (including piezoelectric, electrostrictive, and electrostatic) lack the combination of sufficient strain and force to most effectively perform the aforementioned functions. Previous concepts for shaping and tuning membrane structures have primarily involved the use of piezoelectric ceramic materials. These ceramic piezoelectrics have the major problems of large mass, high density, low strain and high brittleness. Generally, piezoceramics also need additional mechanical devices to achieve a shaping, tuning, positioning, controlling or deforming function. In contrast to electroceramics, electroactive polymers are emerging as new actuation materials due to their enhanced strain capabilities.

Tension control of membranes, using electrostrictive polymer actuators exhibiting at least predominantly single axis displacement and having sufficient force and strain, to smooth local surface wrinkles which may result from thermal distortions and other sources is desirable and currently lacking in the related art.

Summary of the Invention

Accordingly, an object of the present invention is to provide an electroactive tension control device.

Another object is to provide an electroactive tension control device wherein the electroactive components have small mass, low density, high strain and low brittleness.

Another object is to provide an electroactively controlled inflatable membrane.

Another object is to provide an electroactive tension control device using electrostrictive polymer actuators.

Another object is to provide an electrostrictive polymer actuator exhibiting displacement along a longitudinal axis when electrically activated.

Additional objects and advantages of the present invention are apparent from the drawings and specification that follow.

In accordance with the present invention, an electrostrictive polmer actuator comprises an electrostrictive polymer with a tailorable Poisson's ratio. The electrostrictive polymer is electroded on its upper and lower surfaces and bonded to an upper material layer. The assembly is rolled tightly and capped at its ends. In a membrane structure having a membrane, a supporting frame and a plurality of threads connecting the membrane to the frame, an actuator can be integrated into one or more of the plurality of threads. The electrostrictive polymer actuator displaces along its longitudinal axis, thereby affecting movement of the membrane surface.

Brief Description of the Drawings

A more complete appreciation of the invention and the many of the attendant advantages thereof will be readily attained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

FIG. 1 illustrates a prior art membrane structure.

FIG. 2 illustrates the prior art membrane structure with integrated tension control actuators.

FIGs. 3A and 3B illustrate the actuator layers.

FIGs. 4A and4B illustrate the actuator in its rolled state.

FIG. 4C is a cross-sectional view of FIG. 4B illustrating greater detail of the cap attachment.

Detailed Description of the Invention

Referring now to the drawings, and more particularly to FIG. 1, a prior art multifunctional membrane structure is shown and referenced generally by the numeral 100. Membrane 110 is connected to supporting frame 120 by threads 130. The threads 130 are generally a metallic material. FIG. 1 is a general representation of a membrane structure; however, the exact shape of the membrane and supporting structure may vary from that shown. FIG. 2 illustrates electrostrictive polymer actuators 140 integrated into threads 130. The actuators 140 expand or contract along the axis of the threads, thereby increasing or decreasing tension in the threads to make local adjustments to maintain the membrane surface in working condition. An actuator 140 can be integrated into one or more threads 130 as desired.

Referring now to FIGs. 3A and 3B, actuator 140 comprises layer 310 of an electrostrictive polymer material having a tailorable Poisson's ratio. The strain in layer 310 increases in one direction as Poisson's ratio tends to zero. Any deviation of Poisson's ratio away from zero will produce off-axis displacement. Such off-axis displacement is preferably minimized. A Poisson's ratio of zero provides the especially preferred single axis displacement. A preferred material is the electrostrictive graft elastomer described and claimed in "Electrostrictive Graft Elastomers", Serial No. _____, filed October 23, 2000, hereby incorporated by reference. The Poisson's ration is tailored via crystal orientation. Layer 310 is electroded 320 on both its upper and lower surfaces. The electrodes 320 can be single surface electrodes or interdigitated electrodes. An interdigitated electrode configuration allows additional options to vary drive voltage to the electrodes depending on the electrode spacing of a particular design. Suitable materials for the electrodes are conductive polymers, such as polypyrrole or ployaniline, or soft metals, such as gold. The surface of layer 310 that is electroded is maximized. Layer 330 is

bonded to the upper electroded layer 310. A suitable bonding material is a chemical adhesive, such as epoxy. It is preferred for layer 330 to be of the same material as layer 310 so that layer 310 can function as either an active or inactive layer depending on whether it is electrically activated. If a different material is used for layer 330, it must be an insulator. The surface area and thickness of the various layers will vary depending upon specific response requirements.

The bonded layers, denoted generally by numeral 340 are tightly rolled, as illustrated in the exploded view of FIG. 4A, so that there is entire surface contact throughout the roll 410. The overall size of the rolled configuration will depend upon the specific response requirements. The caps 420 are affixed onto both ends of the roll 410, as shown in FIG. 4B. The caps 420 maintain the roll 410 in its rolled configuration and also connect the roll 410 to the threads 430. The caps 420 are insulated metal or plastic, with plastic being preferred. Referring to FIG. 4C, cap 420 is affixed to the roll 410 by chemical or mechanical bonding means. The preferred bonding means is a chemical adhesive that is cast and cured at room temperature and is compatible with the materials being bonded, such as epoxy. The cap 420 overlaps the roll 410 to the extent necessary to achieve sufficient bonding. The threads 430 are attached to the cap 420 using chemical or mechanical means. Illustrated in FIG. 4C is a mechanical means 440 affixing the thread 430 to the cap 420. The cap 420 is bonded 450 to the roll 410. Again referring to FIG. 1, the longitudinal axis of each actuator 140 is substantially aligned with the direction of the thread 130 within which it is integrated. In operation, the actuators 140 respond to the output of sensors located on membrane 110 via an integrated feedback control system.

Obviously, numerous additional modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than is specifically described herein.

What is claimed is:

Claims:

1. A membrane structure, comprising:

a membrane whose position is to be controlled;

a supporting frame;

a plurality of threads connecting the membrane to the supporting frame; and

an electrostrictive polymer actuator integrated into at least one thread, the electrostrictive polymer actuator having a longitudinal axis that is substantially aligned with the axis of the thread;

wherein the electrostrictive polymer actuator displaces along its longitudinal axis, thereby affecting movement of the membrane surface.

2. The structure of claim 1, wherein the electrostrictive polymer actuator contracts.

3. The structure of claim 1, wherein the electrostrictive polymer actuator expands.

4. The structure of claim 1, wherein displacement of the electrostrictive polymer actuator affects tension in the thread.

5. The structure of claim 4, wherein tension in the thread affects tension of the membrane.

6. The structure of claim 1, wherein the electrostrictive polymer actuator comprises:

an electrostrictive polymer having a tailorable Poisson's ratio, wherein the electrostrictive polymer is electroded on its upper and lower surfaces;

an upper material layer bonded to the upper electroded surface of the electrostrictive polymer, wherein the electroded electrostrictive polymer and upper material layer form a bonded assembly, wherein the bonded assembly is rolled into a roll having two ends, and further wherein entire adjacent surfaces within the roll contact one another; and

a cap affixed to each end of the roll.

7. The structure of claim 6, wherein the electrostrictive polymer comprises an electrostrictive graft elastomer comprising a backbone molecule which is a non-crystallizable, flexible macromolecular chain, and a grafted polymer forming polar graft moieties with backbone molecules, the polar graft moieties having been rotated by an applied electric field and sustained in the rotated state until the electric field is removed.

8. The structure of claim 6, wherein the electrostrictive polymer is electroded with a conductive polymer.

9. The structure of claim 6, wherein the electrostrictive polymer is electroded with a soft metal.

10. The structure of claim 6, wherein the electrostrictive polymer is electroded with materials selecting from the group consisting of polypyrrole, polyaniline, and gold.

11. The structure of claim 6, wherein the electrostrictive polymer is electroded with single surface electrodes.

12. The structure of claim 6, wherein the electrostrictive polymer is electroded with interdigitated electrodes.

13. The structure of claim 6, wherein the upper material layer is selected from the group consisting of insulator and electrostrictive polymer.

14. The structure of claim 6, wherein the upper material layer is an electrostrictive polymer having a tailorable Poisson's ratio.

15. The structure of claim 6, wherein the cap is selected from the group consisting of plastic and insulated metal.

16. The structure of claim 6, wherein the cap is affixed to the end of each roll by means selected from the group consisting of chemical and mechanical.

17. The structure of claim 6, wherein the cap is affixed to the end of each roll by epoxy bonding.

18. The structure of claim 6, wherein the thread is affixed to the cap by mechanical means.

19. An electrostrictive polymer actuator, comprising:

an electrostrictive polymer having a tailorable Poisson's ratio, wherein the electrostrictive polymer is electroded on its upper and lower surfaces;

an upper material layer bonded to the upper electroded surface of the electrostrictive polymer, wherein the electroded electrostrictive polymer and upper material layer form a bonded assembly, wherein the bonded assembly is rolled into a roll having two ends, and further wherein entire adjacent surfaces within the roll contact one another; and

a cap affixed to each end of the roll.

20. The structure of claim 19, wherein the electrostrictive polymer comprises an electrostrictive graft elastomer comprising a backbone molecule which is a non-crystallizable, flexible macromolecular chain, and a grafted polymer forming polar graft moieties with backbone molecules, the polar graft moieties having been rotated by an applied electric field and sustained in the rotated state until the electric field is removed.

21. The structure of claim 19, wherein the electrostrictive polymer is electroded with a conductive polymer.

22. The structure of claim 19, wherein the electrostrictive polymer is electroded with a soft metal.

23. The structure of claim 19, wherein the electrostrictive polymer is electroded with materials selecting from the group consisting of polypyrrole, polyaniline, and gold.

24. The structure of claim 19, wherein the electrostrictive polymer is electroded with single surface electrodes.

25. The structure of claim 19, wherein the electrostrictive polymer is electroded with interdigitated electrodes.

26. The structure of claim 19, wherein the upper material layer is selected from the group consisting of insulator and electrostrictive polymer.

27. The structure of claim 19, wherein the upper material layer is an electrostrictive polymer having a tailorable Poisson's ratio.

28. The structure of claim 19, wherein the cap is selected from the group consisting of plastic and insulated metal.

29. The structure of claim 19, wherein the cap is affixed to the end of each roll by means selected from the group consisting of chemical and mechanical.

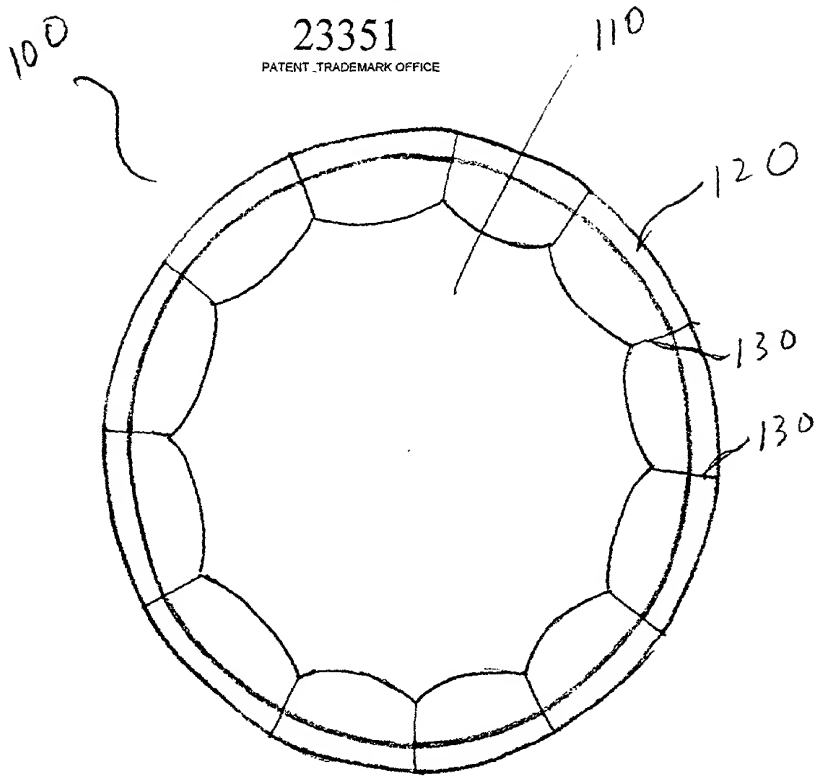
30. The structure of claim 19, wherein the cap is affixed to the end of each roll by epoxy bonding.

-11-

MEMBRANE TENSION CONTROL

Abstract

An electrostrictive polymer actuator comprises an electrostrictive polymer with a tailorable Poisson's ratio. The electrostrictive polymer is electroded on its upper and lower surfaces and bonded to an upper material layer. The assembly is rolled tightly and capped at its ends. In a membrane structure having a membrane, a supporting frame and a plurality of threads connecting the membrane to the frame, an actuator can be integrated into one or more of the plurality of threads. The electrostrictive polymer actuator displaces along its longitudinal axis, thereby affecting movement of the membrane surface.



PRIOR ART
FIG. 1

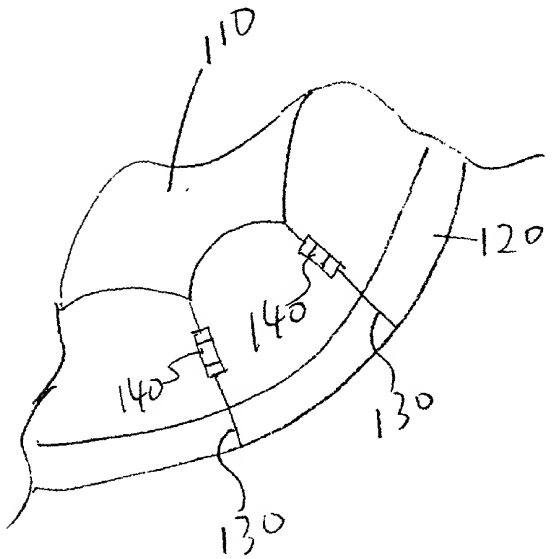


FIG. 2

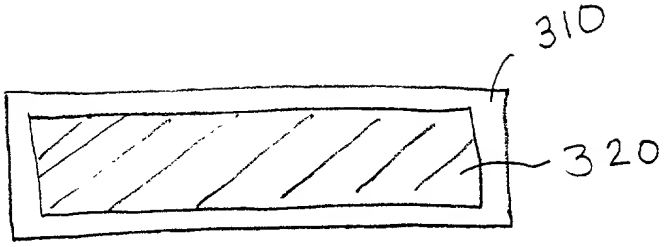


FIG. 3A

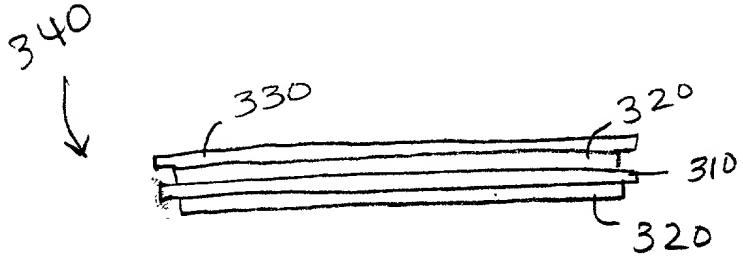


FIG. 3B

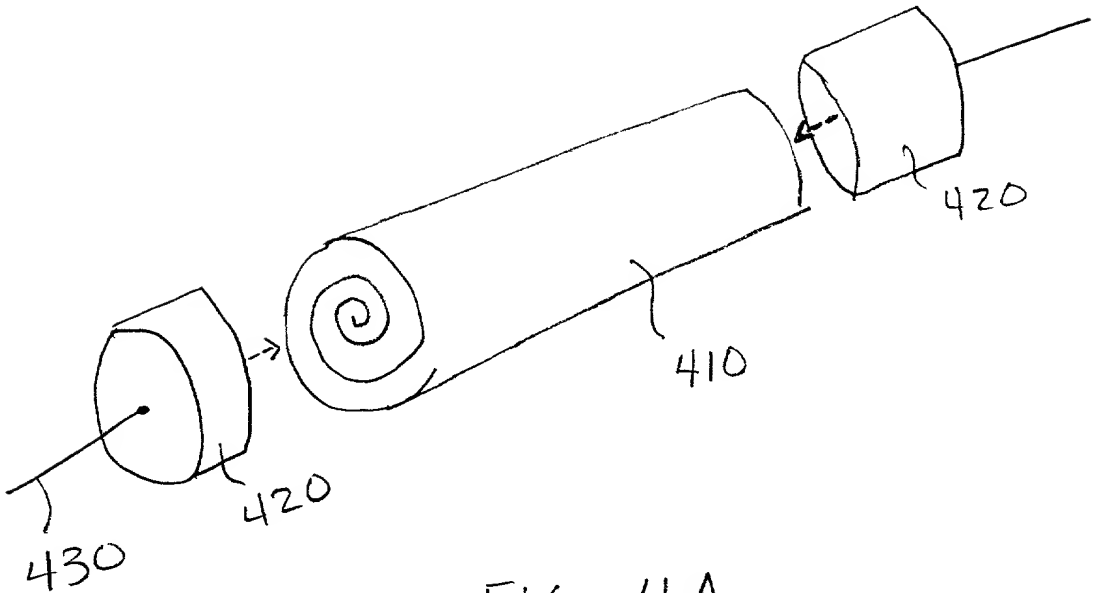


FIG. 4A

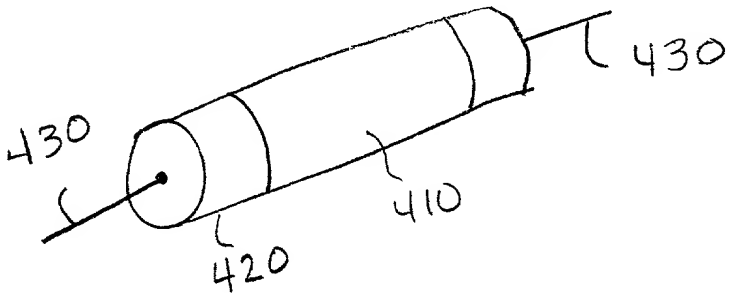


FIG. 4B

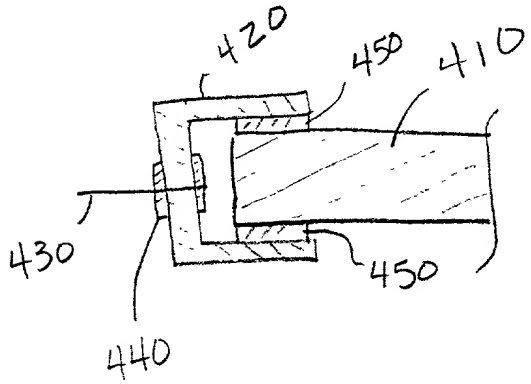


FIG. 4C

National Aeronautics and
Space Administration

NASA Case No.: 16220-1

DECLARATION, POWER OF ATTORNEY AND PETITION - ORIGINAL APPLICATION

As a below named inventor, I hereby declare that: my residence, post office address and citizenship, are stated below next to my name, I believe I am the original, first and sole inventor (If only one name Is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled MEMBRANE TENSION CONTROL, the specification of which ✓ is attached hereto, __ was filed on (Date) _____ as Application Serial No. _____ and was amended on (Date)_____.

I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above

I acknowledge the duty to disclose to the Patent and Trademark Office all information which is known to me to be material to patentability as defined in 37 CFR §1.56.

I hereby claim the benefit under 35 U.S.C. §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of 35 U.S.C. §112, I acknowledge the duty to disclose to the Patent and Trademark Office all information known to me to be material to patentability as defined in 37 CFR §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:____ _ (Serial No.), _____ (Filing Date) ,the status of which is

_ patented, __ pending, _ abandoned.

I hereby claim foreign priority benefits under Title 35, United States Code, § 119(e) of any United States Provisional applications listed below:

PROVISIONAL APPLICATION NUMBER	FILING DATE
60 / **161,113**	**October 22, 1999**
_____ / _____	_____,

the status of which is

_ patented, ✓ pending, _ abandoned.

POWER OF ATTORNEY: I hereby appoint the following attorney(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

LINDA B. B. BLACKBURN	Reg. No. 38,385
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757-864-3522

Further, as a named inventor I certify that the Government of the United States of America, as represented by the Administrator of the National Aeronautics and Space Administration, has x an assignment in, or _ license to the invention set forth in this application and has the irrevocable right to practice this application and to receive the patent.

Wherefore, I pray that Letters Patent be granted to me for this invention or discovery described and claimed in the foregoing specification and claims, and I hereby subscribe my name to the foregoing specification, claims, power of attorney and this petition

I hereby declare that all statements made herein of my own knowledge are true and that - statements made on information and belief are believed to be true; and further that these, statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. §1001; and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

FULL NAME OF INVENTOR	LAST SU	FIRST Ji	MIDDLE OR INITIAL (nmi)
RESIDENCE AND CITIZENSHIP	CITY Highland Park	STATE OR FOREIGN COUNTRY New Jersey	COUNTRY OF CITIZENSHIP U.S.
POST OFFICE	STREET NO. AND NAME 803C Donaldson Street	CITY AND STATE OR (COUNTRY) Highland Park, New Jersey	ZIP CODE 08904
SIGNATURE			DATE

FULL NAME OF INVENTOR	LAST HARRISON	FIRST Joycelyn	MIDDLE OR INITIAL S.
RESIDENCE AND CITIZENSHIP	CITY Hampton	STATE OR FOREIGN COUNTRY Virginia	COUNTRY OF CITIZENSHIP U.S.
POST OFFICE	STREET NO. AND NAME 31 Gunter Court	CITY AND STATE OR (COUNTRY) Hampton, Virginia	ZIP CODE 23666
SIGNATURE			DATE

FULL NAME OF INVENTOR	LAST	FIRST	MIDDLE OR INITIAL
RESIDENCE AND CITIZENSHIP	CITY	STATE OR FOREIGN COUNTRY	COUNTRY OF CITIZENSHIP
POST OFFICE	STREET NO. AND NAME	CITY AND STATE OR (COUNTRY)	ZIP CODE
SIGNATURE			DATE